Available online at www.sciencedirect.com

ScienceDirect

Procedia Earth and Planetary Science 1 (2009) 377–383

Procedia Earth and Planetary Science

www.elsevier.com/locate/procedia

The 6th International Conference on Mining Science & Technology

Study on deep mining safety control decision making system

Li Mei[a]*, Zhang Xiao-ping[b], Mao Shan-jun[a], Liu Quan-sheng[c]

[a]Institute of Remote Sensing and GIS, Peking University, Beijing 100871, China
[b]Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
[c]State Key Laboratory of Geomechanics and Geotechnical Engineering, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan 430071, China

Abstract

More and more coal mines have been turning mining into deep well. Geological environment is complicated and the safety issues are becoming increasingly conspicuous. To realize informationization, intellectualization and visualization of mining safety and high-efficient mining decision, a deep mining safety control decision making system based on Longruan GIS is developed. The system not only fulfills three-dimensional (3D) visualization on geological information such as coal seams, strata, boreholes, crustal stress, gas and water distribution, but also realizes 3D visualization on surveying information such as shafts, roadways and working faces. Moreover, the system stores, queries, computes and analyses various geomechanical parameters which closely associate with safety control decision making, and provides a visual, simple and high-efficient software tool for deep well mining under high crustal stress, high gas thickness as well as high seepage water pressure conditions.

Keywords: deep well; deep mining; 3D visualization; geomechanics; decision making

1. Introduction

More and more coal mines are turning mining into deep well in recent years. Under the influence of high crustal stress, high gas thickness and high seepage water pressure conditions in deep mining, the accidents such as rock burst, coal-gas outburst, mine water inrush are more likely to happen and the difficulties in roadway safety support increase. Mining environment is more complicated and the safety issues are becoming increasingly conspicuous. The experiments and engineering practice indicate that in deep mine the geological environment is complicated, the safety issues caused by geological conditions are increasing, the relationships among different geological conditions are more complicated, and the influence of geological environment on safety mining becomes particularly evident.

Nowadays, the study of the influence of geological environment on safety mining is rare, moreover, intelligent safety mining decision making considering different geological environment is almost unknown[1]. In most coalmine, safety mining decide making and operation management are put into execution by empirical statistics and unthinking action is inevitable. Due to these reasons, the deep mining safety control decision making system is required. The system, applied technologies of GIS, 3D visualization, decision making and based on investigation and comprehensive analysis of geological information in typical deep mining, aims at actual conditions of deep mining and impacts of geological environment on deep mining, and tries to explore a new way to solve deep mine safety and to offer high-efficient mining technological issues using information technology.

* Corresponding author. Tel.: +86-10-62755420; fax: +86-10-62751187.
E-mail address: mli@pku.edu.cn.

doi:10.1016/j.proeps.2009.09.060

2. Expected goal and research method

2.1. Expected goal

The deep mining safety control decision making system is designed and developed according to the theory of deep mining safety decision making under the circumstance of high crustal stress, high gas thickness and high seepage water pressure. The system establishes the basic geological and surveying spatial database and geomechanical parameter database, fulfills the multi-source information integration under 3D visualization, improves efficiency of management and query of basic geological data for deep mining dynamic disaster, accomplishes both qualitative analysis and quantitative computation, and realizes the scientific control and intelligent decision making of deep mine dynamic disaster for safety mining.

On the basis of above analysis, the system needs to reach 2 expected goals.

- Fulfill the general integration and database management of deep mine geological basic information in the demonstration coal mine, including the database management and 3D visualization of stratum, borehole, roadway, working face, crustal stress field, hydrologic geology, gas distribution and so on;
- Fulfill the scientific safety control and intelligent decision making for deep mine. More specifically, according to the actual tasks, analyze the roadway rock stability and evaluate the possible dynamic disasters based on crustal stress, surrounding rock classification, gas distribution and hydrologic geology information, then mark the research area into various sections according to the classification of dynamic disasters, finally give the advice to different roadway and working face arrangement, give the support scheme and recommend the measurement of dynamic disaster prevention and rescue.

2.2. Research method

Fig. 1 shows the research method.

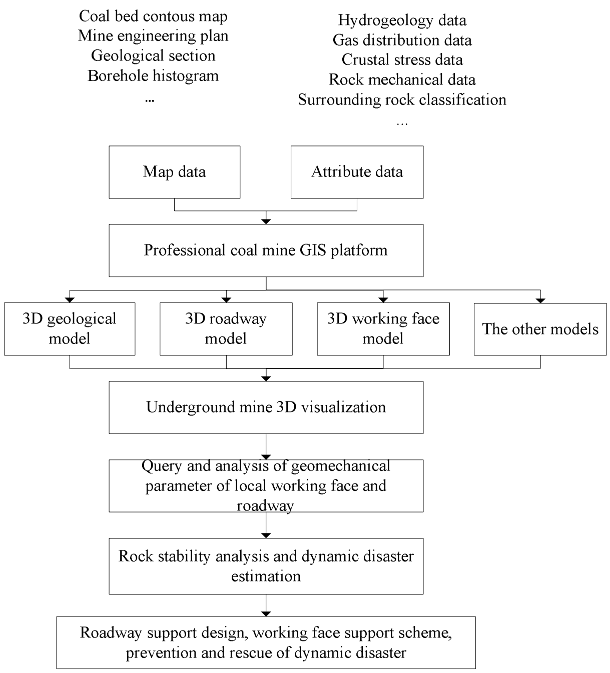

Fig. 1. Research method

- Collect and arrange related geological data, surveying data, hydrological data, historic gas data, crustal stress data and rock mechanical data. Input them into professional GIS system to establish deep mine basic information database. Finally finish data storage, map digitalization and data arrangement;

- Build corresponding 3D geological model, borehole model, roadway model and working face model, ect. Geological model is the most important part, which includes sub-model such as 3D coal seam or stratum model and 3D rock model[2]. ARTP volumes are chosen to build coal seam or stratum surface and closed surfaces make the ARTP's outer boundary[3]. 3D rock model chooses 3D grid volumes. Each gird include the geomechanical attributes, which come from 3D interpolation and statistical forecast by geostatistics[4];
- Display the underground mine 3D models. Realize 3D visualization on geological information such as stratum, borehole, crustal stress, gas and water distribution, and surveying information such as shaft, roadway and working face and on;
- Query and analysis the geomechanical parameter of local working face and roadway during the mining processing. Search the related 3D geological models and obtain their crustal stress, gas, water and surrounding rock parameter;
- Establish the deep mine safety decision making models, which can input the geomechanical parameters of working face and roadway and output the results for roadway support design, working face support design, and dynamic disaster prevention and rescue measurement.

3. System design and key technology

3.1. System design

According to above research goal and method, a deep mine safety control decision making system based on 3D visualization environment is established on the secondary development on the Longruan GIS 3.0 platform.

Longruan GIS 3.0 is a professional coal mine GIS platform created jointly by Peking University and Beijing Longruan Technology. The Longruan GIS platform, developed from the bottom layer in the windows environment with intellectual property right, is applied for coal mine ordinary practical needs. It focuses on large amount of mine spatial data, such as geology, surveying, hydrology reserves, mining, ventilation, transportation, mine design, schedule and so on, fulfills the integrated management of massive spatial data and information share among different systems, establishes multi-layer COM GIS architecture for all specialties, provides flexible secondary development mode, such as API, DLL, ActiveX and Application Template, and provides underground mine 3D visualization and surface industrial square 3D visualization.

Fig. 2 shows the system structure and module partition. The system is composed of database module, 2DGIS+3DGIS module and deep mining safety control decision making module.

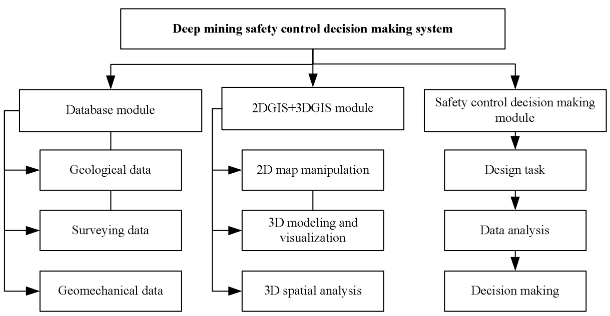

Fig. 2. System structure

The database module is the basis of the whole system. It is charged of data input and management, not only provides 3D geometric modeling data for stratum, borehole, and roadway, but also provides 3D attribute modeling data of crustal stress, hydrological data, and gas distribution data. SQL server2000 is chosen to develop geological database, surveying database and geomechanical parameter database and to realize the networked, multi-layer and multi-user data management.

2DGIS+3DGIS module is the core of the whole system. With secondary development of LongruanGIS, the functions of 2D map manipulation, 3D modeling and visualization is realized. The module, with functions of powerful similar CAD map edition and GIS flexible spatial analysis, can automatically build coal seam models, roadway models, and borehole models with topological relationship, describe the rock structure by 3D regular or irregular grid, and provide functions of 3D cutting, dynamic simulation, information query, reserve computation.

Safety control decision making module is the application module aim to the users. It takes 3D geological model as base, builds up the analysis model of surrounding rock classification, gas distribution, water disaster and crustal stress, finally gives dynamic disaster evaluation, and provides a visual, simple and accurate analysis for roadway support, working face support schedule, and much else.

3.2. Key technology

According to the system design, the key to make a successful system is to realize quick establishment of 3D geological model and 3D visualization, analyze and obtain geological data from 3DGIS platform for decision making. Therefore, key algorithms of 3D geological modeling, 3D spatial analysis and deep mining safety control decision making are introduced briefly in the following.

3.2.1. Technology of 3D geological modeling

3D geological modeling includes coal seam (stratum) modeling and rockmass modeling. The principle of coal seam or stratum modeling is to establish irregular triangulated network (TIN) with topological relationship. Detailed explanation is given in Ref. [3]. Rockmass modeling is to build regular or irregular 3D grids according to the TIN surface to describe the rock structure. Rockmass modeling is to divide 3D mesh firstly, shape 3D grid secondly and fulfill the property using geostatistics method finally. The key problem is how to divide several coal seam or strata into corresponding mesh considering fault problem.

Fig. 3 gives the steps of 3D rockmass modeling.

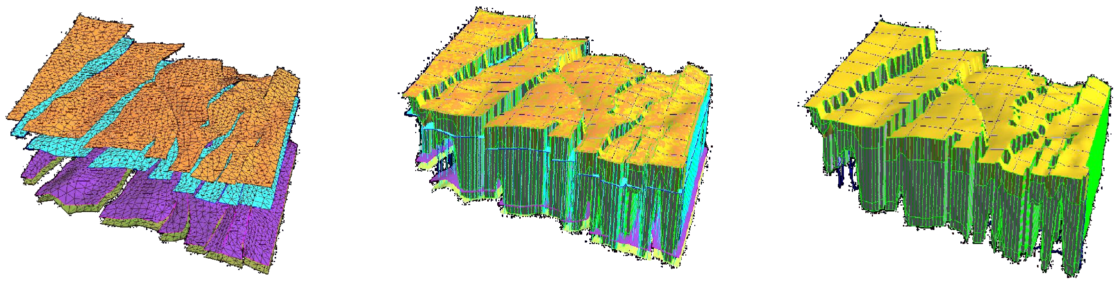

Fig. 3. Steps of 3D rockmass modeling (a) building TIN surface; (b) establish corresponding relationship; (c) building the empty grid

- Build TIN layers for coal seams or strata;
- Establish the correspondences of different layers and divide layers into gird at XY direction;
- Create empty 3D grid model;
- Import geomechanical information, including rock attributes, crustal stress, surrounding rock classification, hydrological data, gas distribution data and so on, then fill the grid model using geostatistics method.

In two types of the models, 3D TIN model describes the geometric shape of coal seam or stratum, while grid model describes the rock structure between the coal layers. Rockmass model scatters rock into a series of hexahedral volumes and each volume carry geomechanical attributions. Users can query these attributes by the given position or observe the attributes by different colors.

3.2.2. Technology of 3D spatial analysis

During the process of safety control decision making, it is the key problem to obtain the corresponding rockmass' attributes of working face or roadway. Here, it is called 3D buffer analysis. With 3D buffer analysis, the system can extract the interesting gird units and obtain their crustal stress, gas parameter, hydrological parameter and other deep mining dynamic disaster parameter for decision making.

3D buffer analysis in coal mine most likely takes roadway driving heads, local roadways or boreholes as the buffer center to create the buffer zone. It means that a simple 3D point buffer or a 3D line buffer is enough for 3D coal mine spatial buffer analysis. Fig. 4 gives the principle of 3D sphere buffer analysis.

The principle of 3D buffer analysis is that: according to given parameters, the system can establish corresponding sphere, cylinder or rectangle 3D buffer zone, mark off the corresponding ranged space of underground mine spatial objects such as strata, faults, roadway driving heads, high gas zones, high crustal stress zones, for querying and analyzing and use for 3D buffer.

The key problem of 3D buffer analysis is to search every 3D models and judge their 3D spatial relationship with 3D buffer zone, mainly including intersect, inclusion, and overlay, then filter the models which intersect with the buffer zone or cover by the buffer zone. After the spatial searching, the corresponding filtered models' attribute can be extracted from the database and provided for decision making.

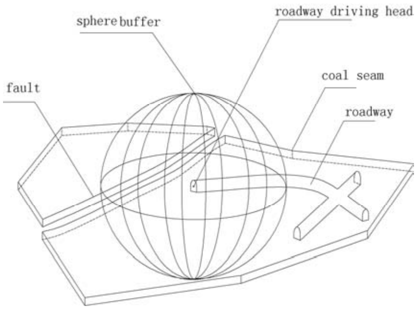

Fig. 4. Sketch map of 3D sphere buffer analysis

3.2.3. Technology of deep mining safety control decision making

The principle of deep mining safety control decision making consists of 2 steps: data analysis and decision making. Firstly the position of development roadway is input into the system, and surrounding information of geology, crustal stress, rock classification, hydrology and gas distribution is output. Data analysis is to analyze the geological information, surrounding rock information, crustal stress, rock classification and hydrological condition, then to establish analysis model for different areas or sections, ensure their basic physical and mechanical parameters, compute the roadway stability under the different support condition by invoking the roadway surrounding rock stability analysis and computation program, and finally give the support scheme or advice. Once the scheme cannot satisfy the use's requirements, the 3D geological model and the attribute information can be exported into the other numerical calculation and simulation software to get a better result.

The main flow is shown as Fig.5, includes:

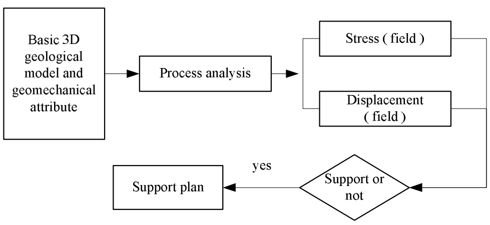

Fig. 5. The flow chart of safety control decision making

- Propose a design task, such as new roadway building, working face scheduling, working face mining, rush to deal with engineering emergency, and so on;

- Choose the analysis module;
- Compute, analyze and make decision. If the result is satisfied with the task requirement, the result is provided to the user. Otherwise the detail analysis is needed;
- Export the 3D geological model and the attribute information into the other numerical calculation and simulation software to make an essential numerical calculation;
- Present the support report base on the analysis and calculation.

4. System design and key technology

The deep mining safety control decision making system is established primarily by using Wangfenggang coal seam, Huainan coal mine, from A group to C group geological and surveying data. Fig.6 shows Wangfenggang underground mine 3D visualization and geomechanical data query.

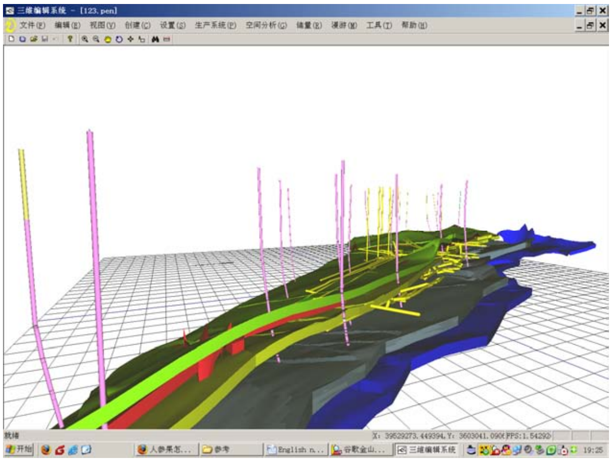

Fig. 6. 3D underground visualization of Wanggenggang mine

5. Results and discussion

With the increase of mining depth and mining intensity, underground mine geology condition is becoming more and more complicated. Dynamic disasters such as rock burst, coal and gas outburst, and water outburst and roadway deformation severely threaten the workers' life and safety, which constraints the coalmine industrial development. For these reason, new high technology is needed to use to eliminate the present potential safety hazard.

In the paper, the research method, system structure and key technology of the deep mining safety control decision making system is introduced. Following is the system's advantages:

- The system establishes a integrated database for deep mine geomechanical data management, realizes the integrated information management, stores and manages the data of geology, surveying, crustal stress, hydrology, gas, and promotes the data usage efficiency;
- The system realizes the geomechanical data visualization, realizes 3D modeling of coal seams, strata, roadways, boreholes, and displays the crustal stress, hydrology, gas distribution in the 3D environment, and provides visual query for 3D platform;
- The system can make decision under the 3D visualization platform. According to the task, the corresponding data is invoked, analyzed and computed automatically and the reliable results will be provided for the users.

References

[1] S. Wang, Geological nature of rock and its deduction for rock mechanics, Chinese Journal of Rock Mechanics and Engineering. 28 (2009) 433.

[2] S. W. Houlding, 3D geoscience modeling – computer techniques for geological characterization. Springer Verlag, New York, 1994.

[3] S. Mao, Gray geographical information system-the theory and technology of correct geological spatial data dynamically, Acta Scientiarum Naturalium Universitatis Pekinensis.38 (2002) 556.

[4] A. Marcus, Development of a 3D GIS based on the 3D modeller Gocad, IAMG Meeting, Cancun, (2001) 256.